U.S. DEPARTMENT OF COMMERCE
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PB-268 015

National Assessment of the Urban Particulate Problem Volume XIV. Miami, Florida

GCA Corp, Bedford, Mass GCA Technology Div

Prepared for

Environmental Protection Agency, Research Triangle Park, N C Office of Air Quality Planning and Standards

Jun 76

PB 268 015

EPA-450/3-76-026l
June 1976

NATIONAL ASSESSMENT OF THE URBAN PARTICULATE PROBLEM

Volume XIV .

Miami

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U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Air and Waste Management
Office of Air Quality Planning and Standards
Research Triangle Park, North Carolina 27711

EPA 450/3-76-028d

National Assessment of the Urban Particulate Problem
Volume XIV - Miami

Becky S. Epstein, David A. Lynn, Frank Record,
Project Director

GCA Technology Division
Bedford, MA 01730

June 1976

GCA-TR-76-25-G(15)

68-02-1376

Final

U. S. Environmental Protection Agency,
Office of Air Quality Planning and Standards
Research Triangle Park, North Carolina 27711

Supplementary Notes: Volume I, National Assessment - EPA 450/3-76-024; Volume II, Particle Characterization - EPA 450/3-76-025; Volumes III-XVI, Urban Area Reports - EPA 450/3-76-028a thru 028p.

This document is one volume of a sixteen-volume report presenting an overall assessment of the particulate problem, which was conducted by GCA/Technology Division, for EPA.

This particular document is one of fourteen study-area volumes that provide working summaries of data gathered in the fourteen urban areas studied. These city reports primarily provide documentation and background information for Volume I of the study - National Assessment of the Particulate Problem - Final Report. Volume I should be considered the primary output of the report.

Key Words and Document Analysis

Descriptors:
Particulate Matter
Total Suspended Particulate
Emission Sources
Control Methods
Air Quality Measurements

Identifiers:
Optical Microscopy
Secondary Particulates
Fuel Combustion
Process Emissions
Fugitive Emissions
Fugitive Dust
Monitor Siting
Meteorology

Availability Statement: Release Unlimited. Available for sale thru the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22151

Security Class (This Report): Unclassified

Security Class (This Page): Unclassified

No. of Pages: 61

Price: $5.00 PC
$3.00 MF

EPA Form 2220-1 (9-73)

EPA-450/3-76-026L

NATIONAL ASSESSMENT OF THE URBAN PARTICULATE PROBLEM

Volume XIV
Miami, Florida

FINAL REPORT

by
Becky S. Epstein
David A. Lynn
Frank Record, Project Director

OCA/Technology Division
Burlington Road
Bedford, Massachusetts 01730

Contract No. 68-02-1376, Task Order No. 18

EPA Project Officer: Thompson G. Face

Prepared for

ENVIRONMENTAL PROTECTION AGENCY
Office of Air and Waste Management
Office of Air Quality Planning and Standards
Research Triangle Park, North Carolina 27711

June 1976

(a)

This Final Report was furnished to the Environmental Protection Agency by the GCA Corporation, GCA/Technology Division, Bedford, Massachusetts 01730, in fulfillment of Contract No. 68-02-1376, Task Order No. 18. The opinions, findings, and conclusions expressed are those of the authors and not necessarily those of the Environmental Protection Agency or of the cooperating agencies. Mention of company or product names is not to be considered as an endorsement by the Environmental Protection Agency.

FOREWORD

This document is part of a 16-volume report assessing the urban particulate problem, which was conducted by GCA/Technology Division for EPA.

This particular document is one of the 14 single city volumes that provide working summaries of data gathered in the 14 urban areas during 1974 to support an assessment of the general nature and extent of the TSP problem nationwide. No attempt was made to perform detailed or extensive analyses in each urban area. Rather, the city reports are intended as a collection of pertinent data which collectively form a profile of each urban area. This, in turn contributes to a comparative analysis of data among the 14 areas in an attempt to identify general patterns and factors relating to attainment of the TSP problem nationwide. Such an analysis has been made in Volume I of the study-National Assessment of the Urban Particulate Problem-National Assessment. The reader is referred to this volume as the summary document where the data is collectively analysed.

The 16 volumes comprising the overall study are as follows:

Volume	I - National Assessment of the Urban Particulate problem
Volume	II - Particle Characterization
Volume	III - Denver
Volume	IV - Birmingham
Volume	V - Baltimore
Volume	VI - Philadelphia
Volume	VII - Washington
Volume	VIII - Chattanooga
Volume	IX - Oklahoma City
Volume	X - Seattle
Volume	XI - Cincinnati
Volume	XII - Cleveland
Volume	XIII - San Francisco
Volume	XIV - Miami
Volume	XV - St. Louis
Volume	XVI - Providence

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ACKNOWLEDGMENTS

GCA/Technology Division wishes to sincerely thank those persons and organizations who made significant contributions to this effort. On-going project supervision was provided by Thompson G. Pace of EPA's Control Programs Development Division. The case study in Miami was greatly assisted by the cooperation and helpfulness of the staff of the Dade County Pollution Control Department, particularly Ed Cahill, R.J. Schmitz, and John Dickerson. David Karamarski of the Florida State Department of Pollution Control also provided valuable assistance.

EXECUTIVE SUMMARY

NATURE OF THE AREA

The Southeast Florida Intrastate AQCR consists of the eight counties located along the southern and eastern coasts of Florida. The AQCR extends from the Keys to Indian River on flat, often marshy land. Dade County, with which this study is primarily concerned, is in the southeastern corner of the state and the AQCR. Much of the nonurban area outside metropolitan Miami is part of the Everglades swamp. The Miami area is a lightly-industrialized resort and retirement community. Major employment groups are the wholesale and retail trades, professional services, and manufacturing.

METEOROLOGY AND CLIMATOLOGY

The climate in Miami is marine subtropical influenced by the Gulf Stream. The average annual temperature is 75°F, with little seasonal variation. Rainfall is moderate to heavy, averaging about 60 inches, and winds are moderate with seasonal directions: northerly in the winter and east to southeast during the remainder of the year. Wind speeds and mixing heights are such as to normally prevent the occurrence of inversions over the city.

AIR QUALITY LEVELS AND TRENDS

The 1975 geometric mean TSP concentrations in Dade County ranged from 42 $\mu g/m^3$ to 86 $\mu g/m^3$. In general, patterns of TSP levels do not obviously relate to conventional land-use categories (residential, commercial) but

rather reflect more local conditions. The citywide mean TSP concentration for 1974 was 59 $\mu g/m^3$, nearly meeting the national secondary standard (60 $\mu g/m^3$). Seven of the 17 sites had annual means above that standard, and two did not meet the primary standard of 75 $\mu g/m^3$. The 24-hour primary standard = 260 $\mu g/m^3$ - was not exceeded in 1974, while the secondary standard of 150 $\mu g/m^3$ was exceeded at three of the stations; the greatest frequency of violations was 10 percent of the observations at the same site that had the second highest 1974 mean TSP level = 79 $\mu g/m^3$.

Sampling in the Miami area began in 1965 with eight stations, and by 1974 there were 17 sites sampling at least part of the year. TSP levels have fluctuated over time with peak years being 1971 and 1973 at most sites. 1974 levels were somewhat higher than 1967, averaging about 10 $\mu g/m^3$ higher over the entire city.

SOURCES AND EMISSIONS

Miami, as a lightly industrialized city, has only 3,900 TPY emissions from industrial processes, mostly from cement plants. Stationary source fuel combustion contributes about 1,400 TPY and motor vehicles another 4,900 TPY. Fugitive emissions from quarries were estimated separately from the rest of the emissions inventory to be about 29,300 TPY. Excluding the estimates from quarries, emissions from the traditional sources are thus 62 percent of the total; the figure would be 69 percent with the quarries included as traditional sources.

NETWORK DESIGN

The 17 sampling sites in the Miami area are distributed well throughout the urbanized area. Their monitoring heights are generally optimal, ranging from 13 to 35 feet high, and are more consistent than in most urban areas. There are no industrial sites because of the lack of heavy industry in the city. There are, at present, no monitoring sites in the

Everglades; reactivating a monitor there could provide data on background TSP levels and on the extensive swamp fires which occur periodically.

REGULATIONS

Of the 14 cities studied, Miami's visible emissions regulation is typical; though air pollutant emissions darker than Ringelmann No. 1 are not generally allowed, there are many exceptions. Miami's fuel combustion and incinerator emission regulations are average, and the process weight regulations are more stringent than the average. Separate regulations are listed for Kraft pulp mills and Portland cement plant kilns. Open burning with some restriction is allowed in Florida. A reasonable precaution regulation is in effect for sources of fugitive particulates.

URBAN ACTIVITY

Because of the absence of other confounding factors, an extensive analysis of the effect of traffic activity on urban TSP levels was carried out in Miami. Traffic was shown to have an obvious influence on TSP as measured by monitors near the wide, heavily-traveled streets of Miami. Data on particulate lead (Pb) was also investigated. Ambient lead levels were found to correlate to some extent with land use at the various monitoring sites, in general confirming an apparent strong effect of traffic.

FACTORS INFLUENCING AIR QUALITY

Overall, the primary factor influencing citywide TSP levels in Miami is the general level of urban activity, especially vehicular traffic with associated reentrained street dust. The emissions from stationary sources, including fugitive emissions from quarrying operations, no doubt contribute to the overall levels, but with the exception of one site, do not dominate the pattern.

SECTION 1

INTRODUCTION

NATURE OF THE AREA

The Southeast Florida Interstate AQCR (Figure 1) consists of eight counties along the southern and eastern coasts of the Florida peninsula: Broward, Dade, Indian River, Martin, Monroe, Okeechobee, Palm Beach, and St. Lucie Counties. Dade County is the case study area with which we are primarily concerned; it is in the southeastern corner of the AQCR, and includes the metropolitan Miami area as well as a large part of the Everglades swamp.

The Miami area is located along the northern part of the Dade County coastline. To the east of the City of Miami lies Biscayne Bay, an arm of the ocean about 15 miles long and 3 miles wide. East of the area is the island of Miami Beach, a mile or less wide and about 10 miles long, and beyond Miami Beach is the Atlantic Ocean. The countryside surrounding the City of Miami is sparsely wooded and not more than 50 feet above sea level. Nearly half of Dade County is marsh or swampy land, and a sizable portion of that is part of Everglades National Park.

Population and Land Use Patterns

The Miami SMSA is comprised only of Dade County. The land area is 2,042 square miles with a total population (as of 1970) of 1,267,800, or 621 persons per square mile. The Miami urbanized area has 4,715 persons per

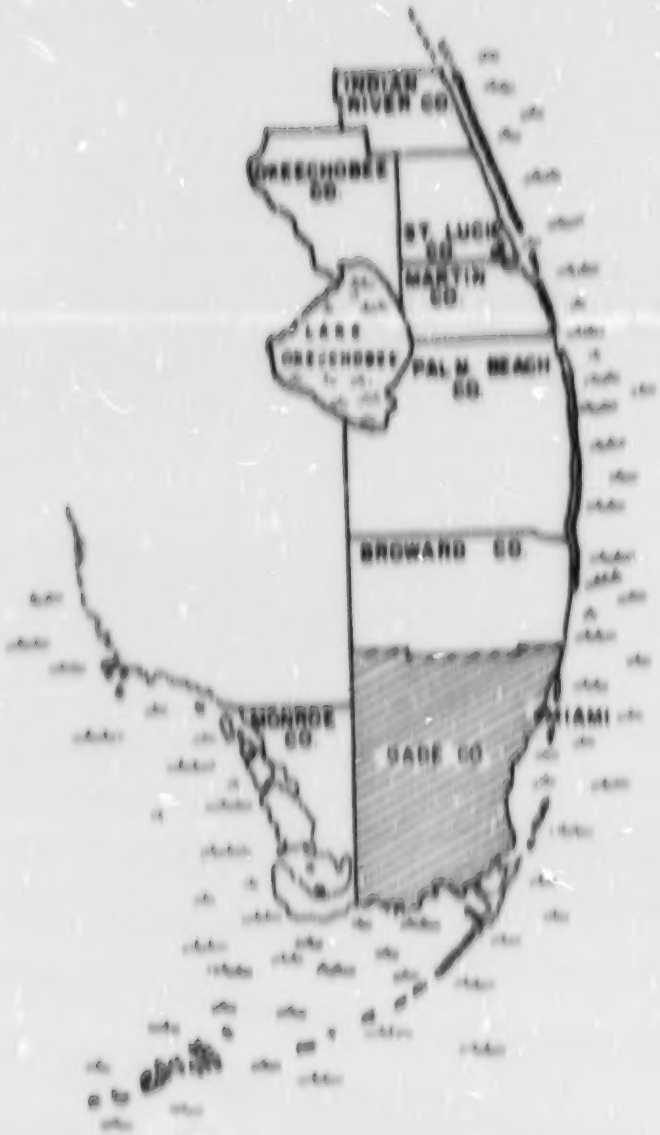


Figure 1. The Southeast Florida Interstate AQCR

square mile: 1,219,661 persons in 259 square miles. The Miami area has a well-defined Central Business District, but there are no heavy industrial areas.

The Miami AQCR is characterized as primarily service-oriented; it is a resort area and retirement community, with a high percentage of people of retirement-age in the area. Of manufacturing industries, the apparel industry is the largest employer, followed by machinery, fabricated metal products and equipment industries. There is no significant amount of heavy industrial activity. Table 1 is a breakdown of employment by category in the Miami SMSA (Dade County). Nearly one-quarter of the employed population is in the wholesale and retail trades, with the next largest employment in the professional and related services category.

Table 1. EMPLOYMENT IN THE MIAMI, FLORIDA SMSA (DADE COUNTY)

Category	Employment	Percent
Construction	27,340	6.3
Manufacturing	63,433	14.5
Transportation, communication, and other public utilities	46,739	10.8
Wholesale and retail trade	101,271	23.5
Finance, insurance and real estate	29,346	6.8
Business and repair services	19,250	4.5
Personal services	36,568	8.5
Professional and related services	68,450	15.9
Public administration	19,281	4.5
All other industries	12,447	2.9
Armed Forces, at work	7,786	1.8
Total	431,122	100.0

Meteorology and Climatology

The climate of Miami is essentially subtropical marine, influenced by the Gulf Stream and featuring a long, warm summer with abundant rainfall, followed by a mild, dry winter. Winds are from the east or southeast during the warmest months, and from northerly directions during the winter.

The cooperative weather station on Miami Beach, at the water's edge, has a normal annual rainfall of about 46 inches while the Weather Service office at the airport, 9 miles inland, has a normal of over 59 inches.

Temperatures in Miami are consistently warm, with an average of only 200 heating degree days per season. Freezing temperatures almost never occur near the ocean. Snow has never been reported. The yearly temperature range is small. Average monthly temperatures at the airport are 67°F in January and February, the coldest months, and 82°F in July and August, the warmest months. Tropical hurricanes occasionally affect the area, the months of greatest frequency being September and October.

Wind speeds are in the middle of the range of the cities studied, both at the surface and through the mixing layer. Morning mixing heights, at 923 m, are the highest of the 14 cities studied, while afternoon heights are average (1351 m). There are frequent short-term night and day inversions, which occasionally extend over 1 or several day periods every year.

AIR QUALITY LEVELS AND TRENDS

During 1974, TSP was monitored at 17 sites in the Miami area. The location of these sites are shown in Figure 2; they are generally distributed throughout the inhabited area of Dade County. There are currently no samplers in the swamp areas, but Site 27, located in the Everglades, was

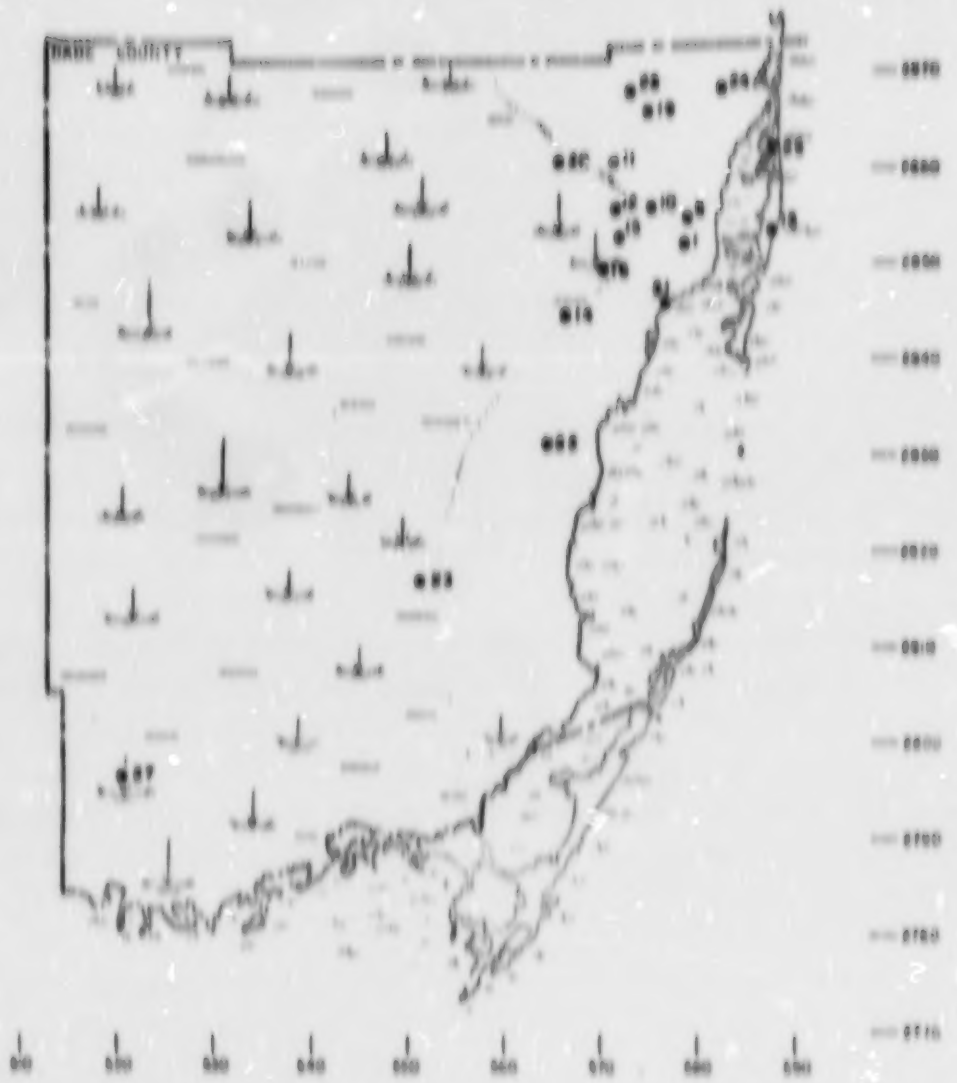


Figure 2. Locations of air quality monitoring sites in Dade County

used in the past as a background sampling site. Annual TSP levels there were 16.5 $\mu g/m^3$ and 22.2 $\mu g/m^3$ in 1972 and 1973.

1974 TSP levels were not high, varying from 86 $\mu g/m^3$ to 42 $\mu g/m^3$ (Figure 3). Only two sites exceeded the national primary annual standard for particulates in 1974. The variations among the sites are not simply a function of conventional land use patterns. As seen in Table 2, center city sites range from 48 $\mu g/m^3$ (commercial) to 73 $\mu g/m^3$ (residential). Miami's highest and lowest TSP levels for the year occurred at suburban residential and commercial sites.

Of the two sites that exceeded the primary standard, one is an "industrial" site (79 $\mu g/m^3$) and the other a suburban-commercial site (86 $\mu g/m^3$) with a fugitive dust problem. Five other sites did not attain the national secondary standards.

The same industrial site exceeded the national secondary 24-hour standard most frequently of all the Miami sites: 10 percent of the sampling days at that site (Table 2). Seven other sites exceeded the secondary standard during the year a maximum of 7 percent of the sampling time. Only two sites exceeded the primary 24-hour standard: a center city-commercial site 3 percent and a suburban-residential site 2 percent of the sampling time.

Historical air quality data is available since 1967 at eight sites, with shorter records from other sites; the trends in levels at all sites are plotted in Figure 4. The citywide average level has increased from about 50 $\mu g/m^3$ to nearly 60 $\mu g/m^3$, with no clear difference in trend among various geographical portions of the area. The most striking feature in Figure 4, in fact, is the strong similarity among many sites in the pattern over the years 1971 to 1974.

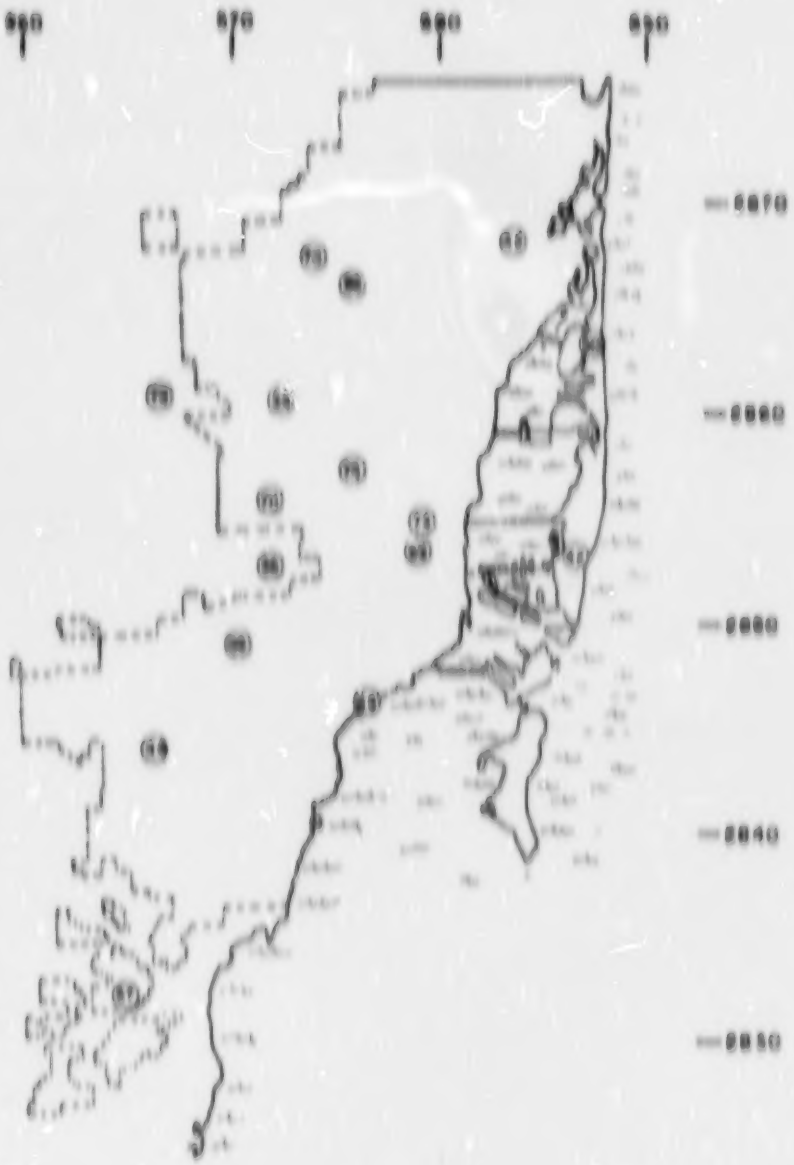
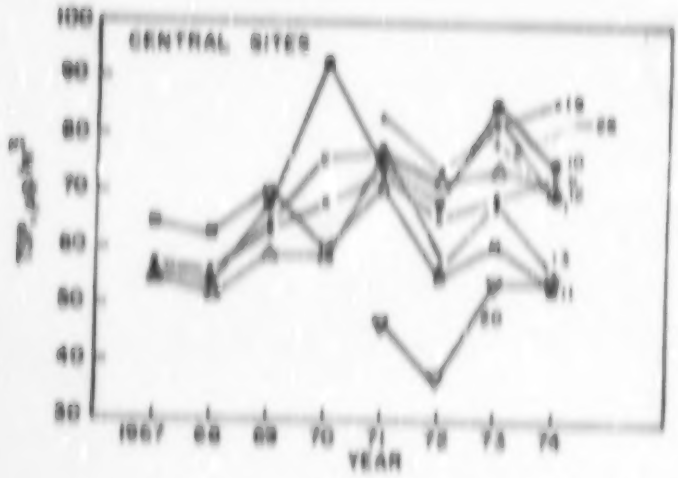
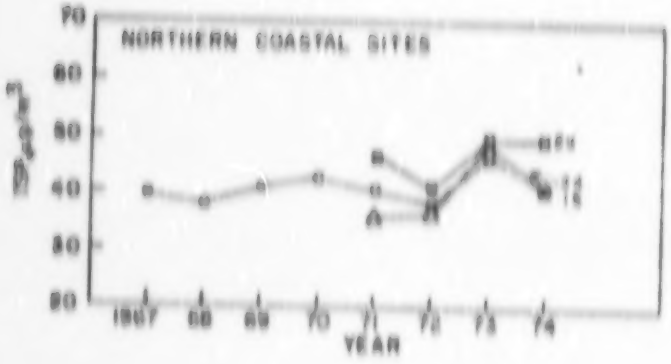


Figure 3. 1974 mean TSP concentrations at sites in the Miami urbanized area

Table 2. 1974 TSP LEVELS AND EXCURSIONS OVER THE STANDARDS, ACCORDING TO LAND USE

Site characteristic	Site No.	1974 mean TSP, $\mu g/m^3$	Percent excursions over national 24-hour standards	
			Primary, 260 $\mu g/m^3$	Secondary, 150 $\mu g/m^3$
Center city-commercial	1	69	2	2
	45	42	0	0
Center city-residential	10	75	0	2
	8	73	0	2
Suburban-commercial	19	86	0	7
	13	56	0	0
	23	48	0	0
	24	42	0	0
Suburban-residential	28	70	0	0
	12	70	0	2
	16	58	2	6
	21	55	0	2
	11	54	0	0
	25	50	0	0
	14	44	0	0
Suburban-industrial	22	97	0	0
Rural-industrial	33	79	0	10





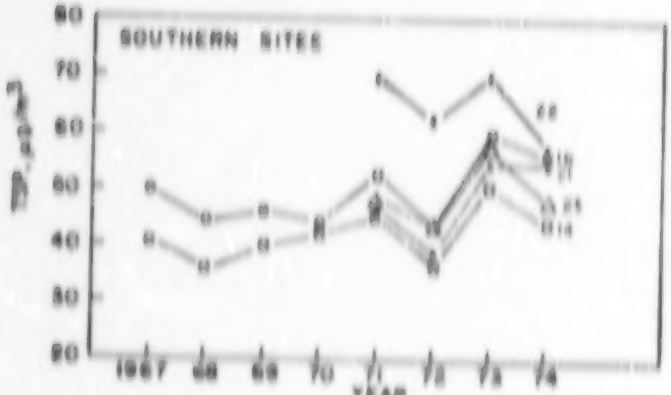


Figure 4. Air quality trends in Miami

SECTION II

ANALYSIS AND DISCUSSION

In this section, the major factors that might be expected to affect TSP levels in Miami are each considered in turn. Included are discussions concerning sources and emissions, control regulations, meteorology and climatology, urban activity factors, and network design and monitor siting.

SOURCES AND EMISSIONS

Miami is very lightly industrialized and also has a very low space heating demand; consequently, it has a relatively low particulate emission level, as summarized in Table 3. The emissions estimates in Table 3 are totaled in two different ways -- with and without the estimate of 29,300 tons per year from quarries, rock crushing, etc. This latter figure represents the result of a special inventorying effort by the staff of the Dade County Pollution Control Agency, which effort goes well beyond that normally employed in conventional inventories. Consequently, the balance of the total inventory is judged a better comparative figure in the national context of this study. Of the conventional inventory of 12,860 tons per year, motor vehicles and cement plants account for the dominant share. The 29,300 tons per year from quarries, however, in turn dominates the entire total of the conventional inventory. This is presumably not atypical of the results that would be obtained in other lightly industrialized areas if estimates of such fugitive emissions were compiled.

Table 3. DADE COUNTY EMISSIONS SUMMARY

	Tons per year	Percent of total not including fugitive emissions	Percent of total
Solid waste combustion	772	6.0	1.8
Fuel combustion			
Power plants	1,364	10.6	3.2
Motor vehicles	4,866	37.8	11.5
Subtotal	6,230	48.4	14.8
Industrial process			
Asphalt	801	6.2	1.9
Cement	4,769	37.1	11.3
Aluminum	81	0.6	<0.1
Lime kiln	187	1.5	0.4
Fruit	20	0.2	<0.1
Subtotal	5,858	45.5	13.9
Total conventional inventory	12,860	100.0	30.5
Fugitive emissions from quarries	29,300		70.5
Total[a]	43,160		100.0

[a]Does not include approximately 10,000 TPY from uncontrolled burning.

In addition to the source categories listed in Table 3, some additional emissions are undoubtedly generated from the sources that have come to be called fugitive dust sources. An EPA study has estimated emissions from several such sources for the entire U.S. on a county-by-county basis; the estimates for Dade County are presented in Table 4. These estimates exceed by an order of magnitude the totals of the conventional inventories. In the context of this project and report they are seen, intuitively, as being quite high and difficult to reconcile with conventional presumptions. For the present, they are merely presented for completeness, pending a thorough assessment.

Table 4. FUGITIVE DUST EMISSIONS ESTIMATES FOR DADE COUNTY

Source	Emissions, tons/year
Unpaved roads	70,900
Dirt airstrips	0
Construction	39,400
Land filling	1,000
Total	111,300

Fuel Usage

Miami's average annual heating demand is an insignificant 206 degree-days, so emissions from space heating are insignificant in the city's particulate pollution. There is some fuel usage in homes, however, and the breakdown by fuel type is displayed in Table 5. In 1950, there were less than 70,000 households with significant fuel usage in Dade County, while in 1970 this number had jumped nearly an order of magnitude to over 360,000, suggesting the growth of the area. Most of the fuel used is gas and electricity; the latter usage is very high, reflecting the limited need for major heating capacity. Some oil is still being used -- in 9 percent of the homes -- but essentially no coal is burned.

Table 5. FUEL USAGE BY NUMBER OF DWELLING UNITS, MIAMI SMSA (DADE COUNTY)

Fuel	1950	1960	1970	Percent change 1950 to 1970
Gas	13,605	105,660	126,974	+714
Oil	8,800	62,714	31,763	+261
Coal	685	736	76	-89
Electricity	12,220	56,875	203,023	+1,561
Total	37,310	225,985	361,836	+870

Data on industrial electricity usage were not available, but of the other fuels, gas is the most favored for industrial purposes; virtually no coal or coke is used in Dade County (see Table 6). Gas and oil were used almost equally in 1963, but more recently gas usage has become predominant.

Table 6. FUEL USAGE BY INDUSTRY, MIAMI SMSA (DADE COUNTY)

Fuel	1963	1972	Percent change
Gas ($10^6 ft^3$)	681	3,900	+473
Oil (1000 bbl)	779	499	-35

REGULATIONS

The regulations adopted by Florida and Dade County, which are essentially similar, were compared to the regulations of the other study cities and in some cases to regulations for all other states. Florida's regulations include sections on visible emissions, fugitive particulates, incinerators and general manufacturing processes. Separate regulations are provided for several specific types of sources, including Portland cement plants. The regulations also govern odor emissions, volatile organic emissions, and complex and mobile sources, and provisions for permits and open burning are included. The Florida regulations for fuel combustion and incinerator emissions regulations are about average, and the process weight regulations are more stringent than average. Reasonable precautions are prescribed for the control of fugitive particulates, which is a common approach in this situation, and the visible emissions and open burning regulations are typical.

Fuel Burning

Florida's regulation has two sections on fuel burning: fossil fuel steam generators and carbonaceous fuel burning equipment. For new and existing fossil fuel steam generating plants with more than 250 million Btu per hour input, particulate emissions are limited to 0.1 pounds per million Btu heat input, maximum 2 hour average; as seen in Figure 5 this is about the average restriction on such large combustion units. Smaller plants are required to apply the latest reasonably available technology. Visible emissions are limited to Ringelmann No. 1 except for 2 minutes in any hour, when they may be as dark as Ringelmann No. 2.

The emissions from other carbonaceous fuel burning equipment is regulated separately. For existing equipment with a capacity greater than or equal to 30 million Btu per hour, emissions cannot exceed the sum of 0.3 pounds per million Btu of heat input of carbonaceous fuel and 0.1 pounds per million Btu of fossil fuel. The emission standard for new equipment of this size is the sum of 0.2 pounds per million Btu of heat input of carbonaceous fuel and 0.1 pounds per million Btu of fossil fuel. Visible emissions cannot exceed Ringelmann 1.5 except for 3 minutes in any hour when they may be as dark as Ringelmann No. 2.

Existing and new burners with less than 30 million Btu per hour capacity have no particulate limiting standard. Visible emissions are limited to Ringelmann 1 except for 3 minutes in any hour when they may be Ringelmann 2.

Industrial Processes

The allowable emissions are specified by a process weight rate regulation, which is applicable to all unspecified process emissions, including cement plants. As seen in Figure 6, the specified emission rates are on the stringent side.

Figure 5. Florida fuel-burning emissions regulation

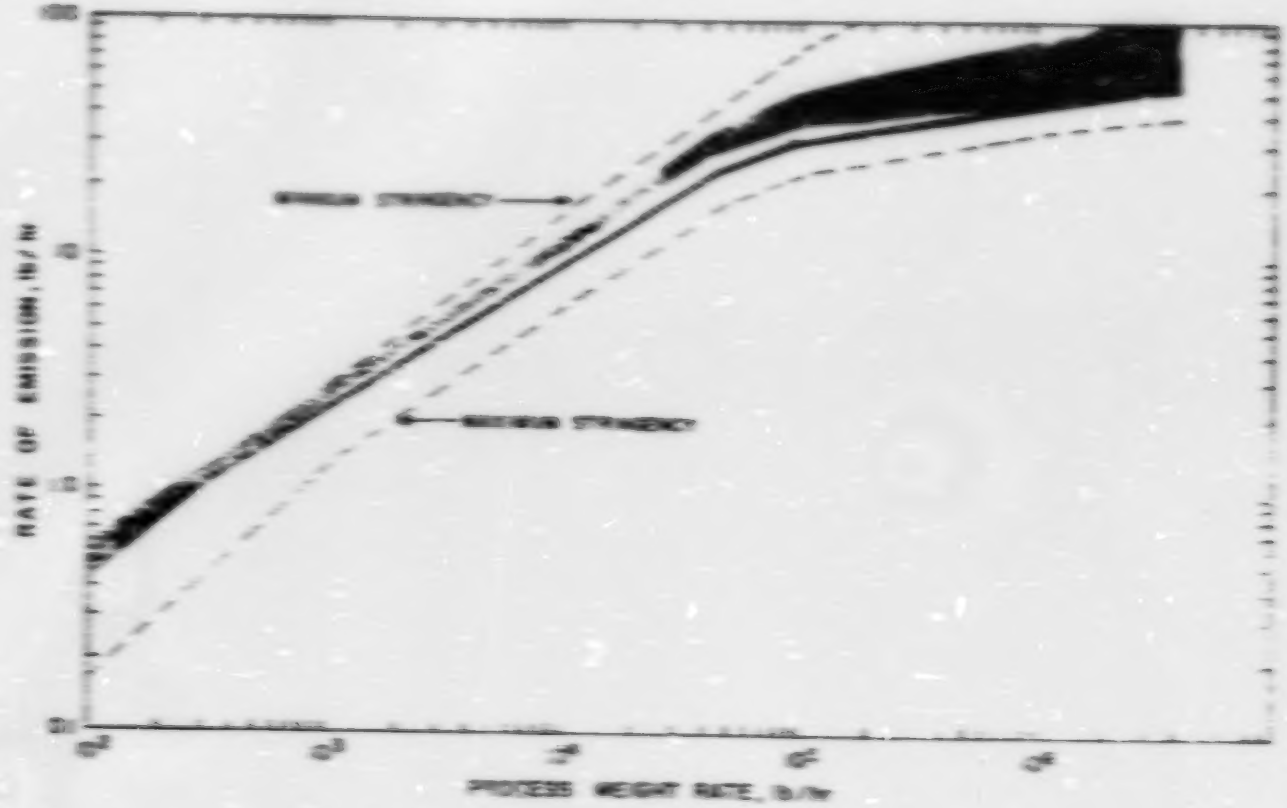


Figure 6. Florida's general process weight regulation

Incinerators

New incinerators with a charging rate greater than or equal to 50 tons per day are limited to 0.08 grains per standard cubic foot of dry gas. For smaller, new incinerators, only the visible emission standard is applicable: visible emissions cannot be darker than No. 1 on the Ringelmann chart for more than 3 minutes in any hour. Existing incinerators with a charging rate of 50 or more tons per day can emit no more than 0.1 grains per standard cubic foot of dry gas, corrected to 50 percent excess air. Other existing incinerators must comply with the regulations for new incinerators.

Open Burning

Certain kinds of open burning are allowed in Florida. Fires for agricultural, silviculturai, and forestry purposes are allowed between the hours of 9 a.m. and 1 hour before sunset, and at other times with Department approval. The same time period is designated for land clearing and demolition fires with additional restrictions based on the proximity of other buildings and highways. The material to be burned in these fires must be in such a condition so as to minimize air pollution and prevent excessive visible emissions, defined as darker than No. 2 on the Ringelmann Chart. Department approval of the type of burning device and fuel to be burned is required for frost protection fires. Industrial, commercial, and municipal burning are allowed with permission and only when no alternative method of disposal exists. Burning on residential property is allowed when refuse collection is not available on a regular basis and with the further restriction that the burning not create a nuisance. Other fires, such as recreational fires and fires for warming outdoor workers, are allowed as long as there is no excessive visible emission. Also allowed are fires built for the instruction of firemen and the flaring of waste gases.

METEOROLOGY AND CLIMATOLOGY

Miami's climate is subtropical; the average annual temperature is 75 degrees. Heating degree days are insignificant (a yearly average of 206) so emissions from space heating are insignificant. There is an average of 4038 cooling degree days per year - 4657 in 1974 - but this would not be expected to significantly affect particulate emissions. (Meteorological data is from Miami International Airport.) Because the air quality situation in Miami is not dominated by massive industrial or space heating emissions, it was considered likely that meteorological effects might be particularly apparent here. The following discussion considered each of the identified meteorological effects in turn.

Precipitation is perhaps the most obvious meteorological influence on TSP levels. Precipitation typically causes a decrease in TSP levels, both by washing particles from the air and by suppressing reentrainment of particulates from the ground. In Miami these effects are seen in the aggregate, although imperfectly, in the relationship between seasonal and historical rainfall and TSP trends. Historically, one can compare the TSP trends with the rainfall record, presented in Figure 7. Citywide TSP levels were lower (Figure 4) between 1967 and 1969, when rainfall was above average. However, between 1969 and 1970 there was a dramatic decline in rainfall with only a moderate increase in TSP, and both precipitation and TSP levels rose between 1970 and 1971. From 1971 to 1973, rainfall levels increased and then decreased, and TSP concentrations followed the inverse of this pattern; but then TSP and rainfall both declined in 1974. Thus the potential inverse correlation between yearly rainfall and particulate levels over the 7-year period is only evident for about half of the years, indicating that some other factors are operating to influence average TSP levels from year to year.

In seasonal patterns there is also no perfect correlation between TSP and either number of days with precipitation or amounts of precipitation. Figures 8 and 9 present the precipitation data, while Figures 10 through 13

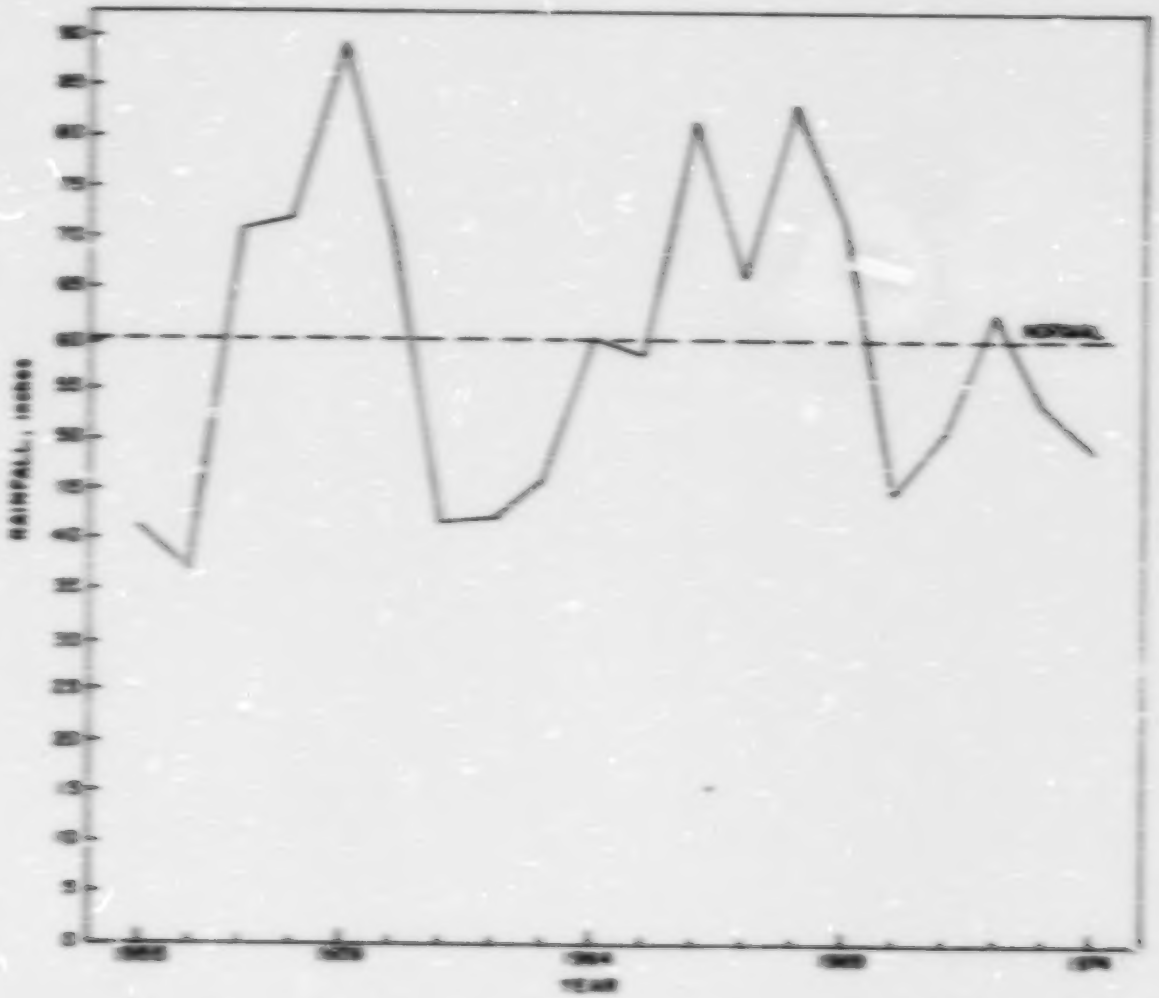


Figure 7. Historical record of annual rainfall in Miami

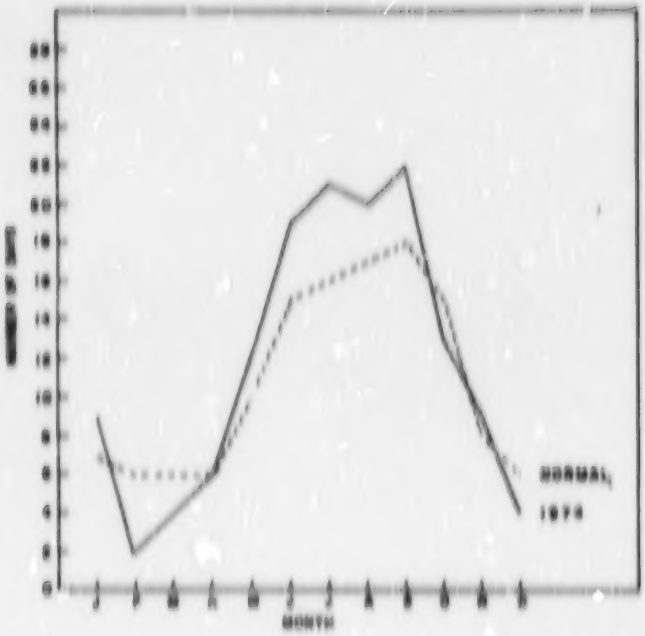


Figure 8. Number of days with precipitation by month in 1974 in Miami

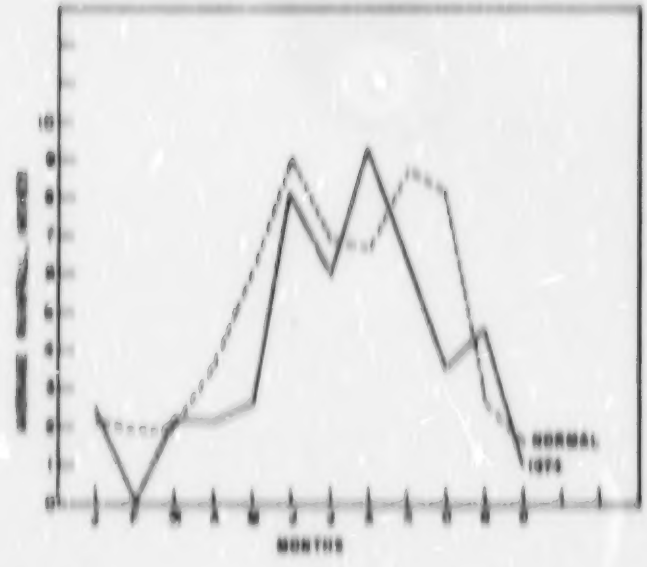


Figure 9. Monthly rainfall in 1974 in Miami

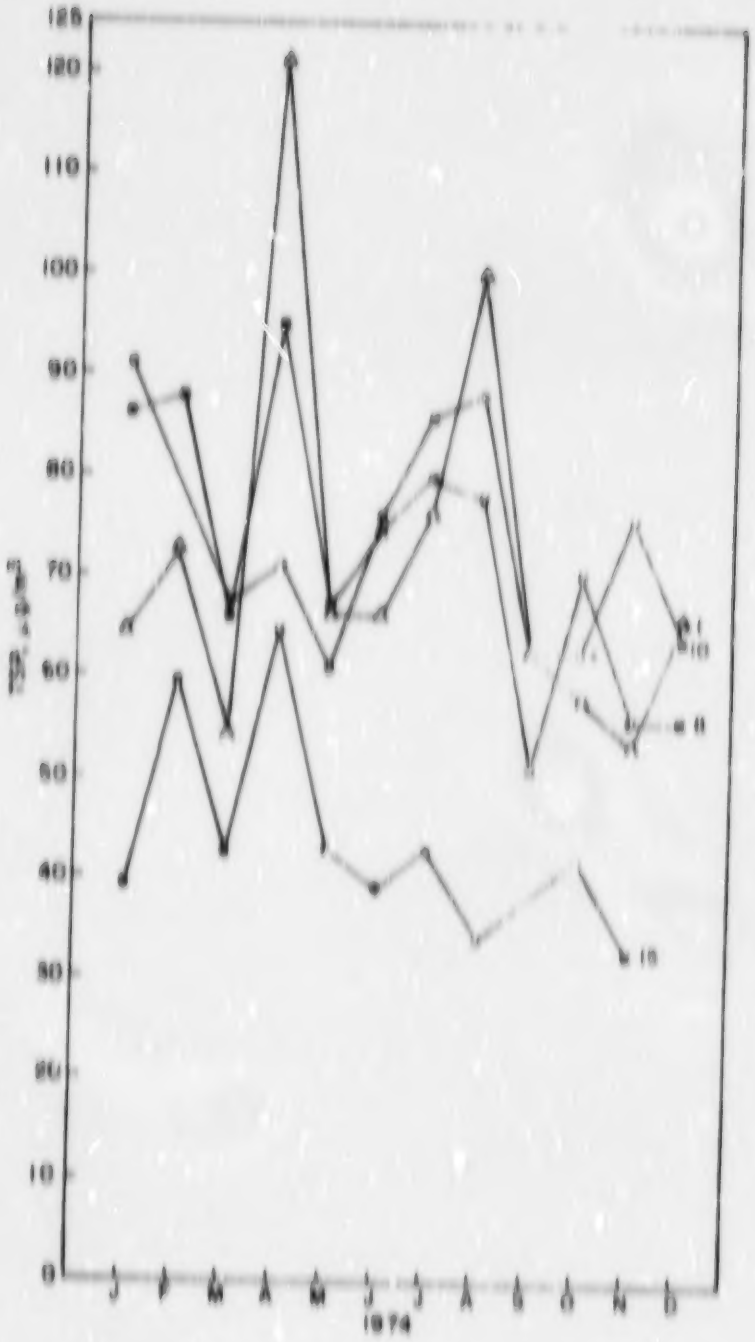


Figure 10. Seasonal TSP patterns at center city sites

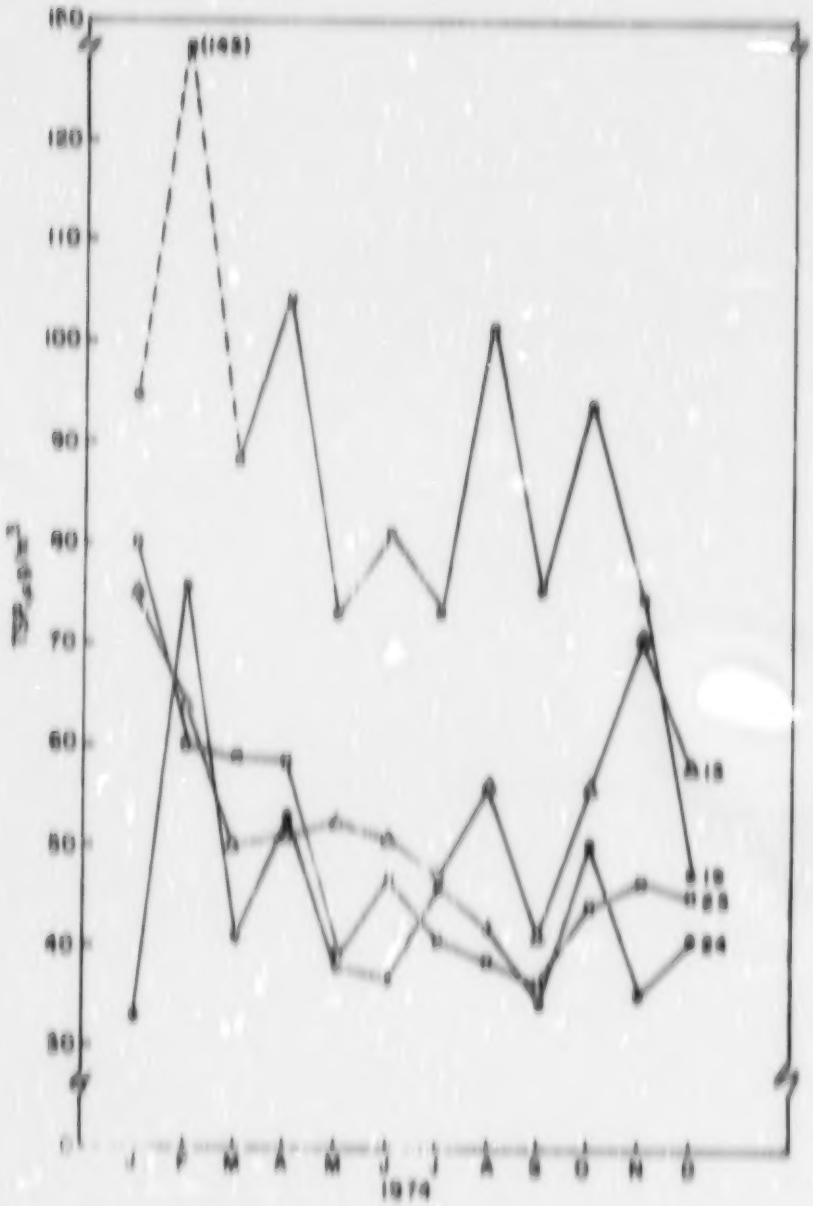


Figure 11. Seasonal TSP patterns at suburban-commercial sites

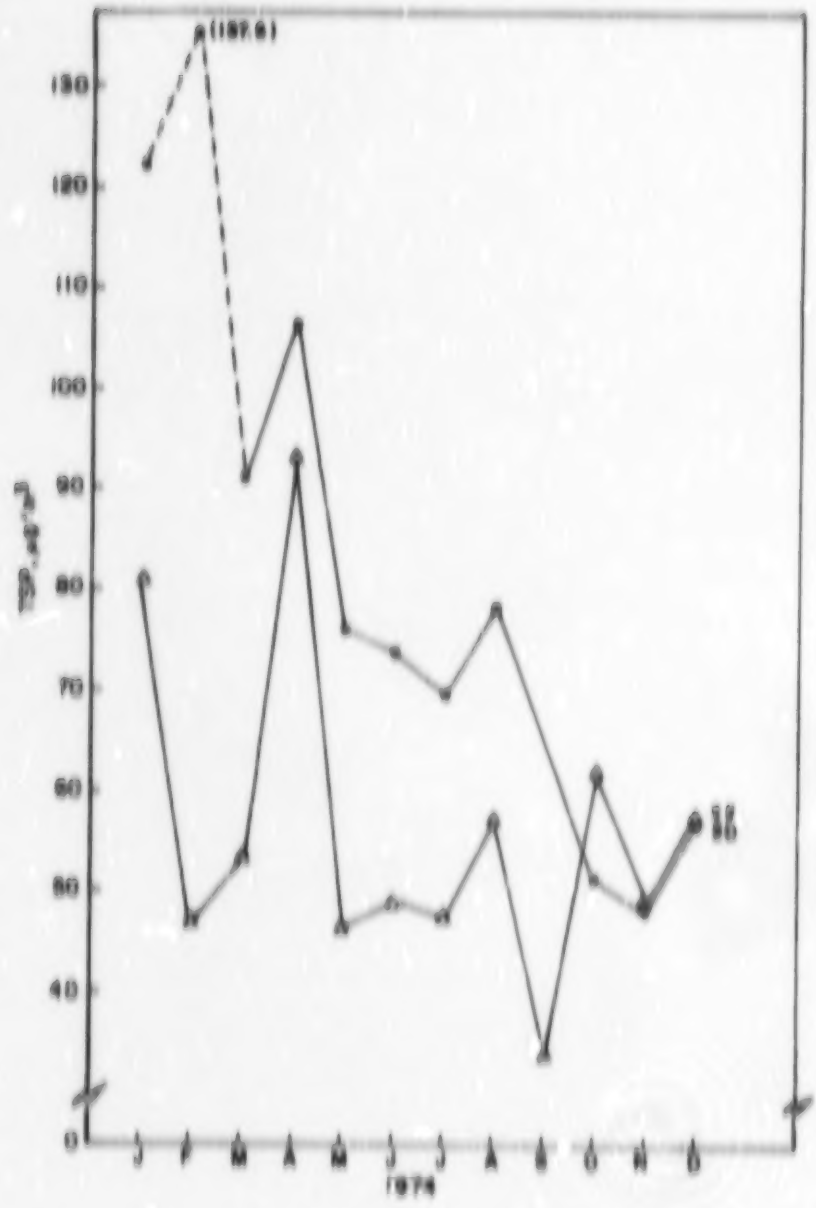


Figure 12. Seasonal TSP patterns at industrial sites

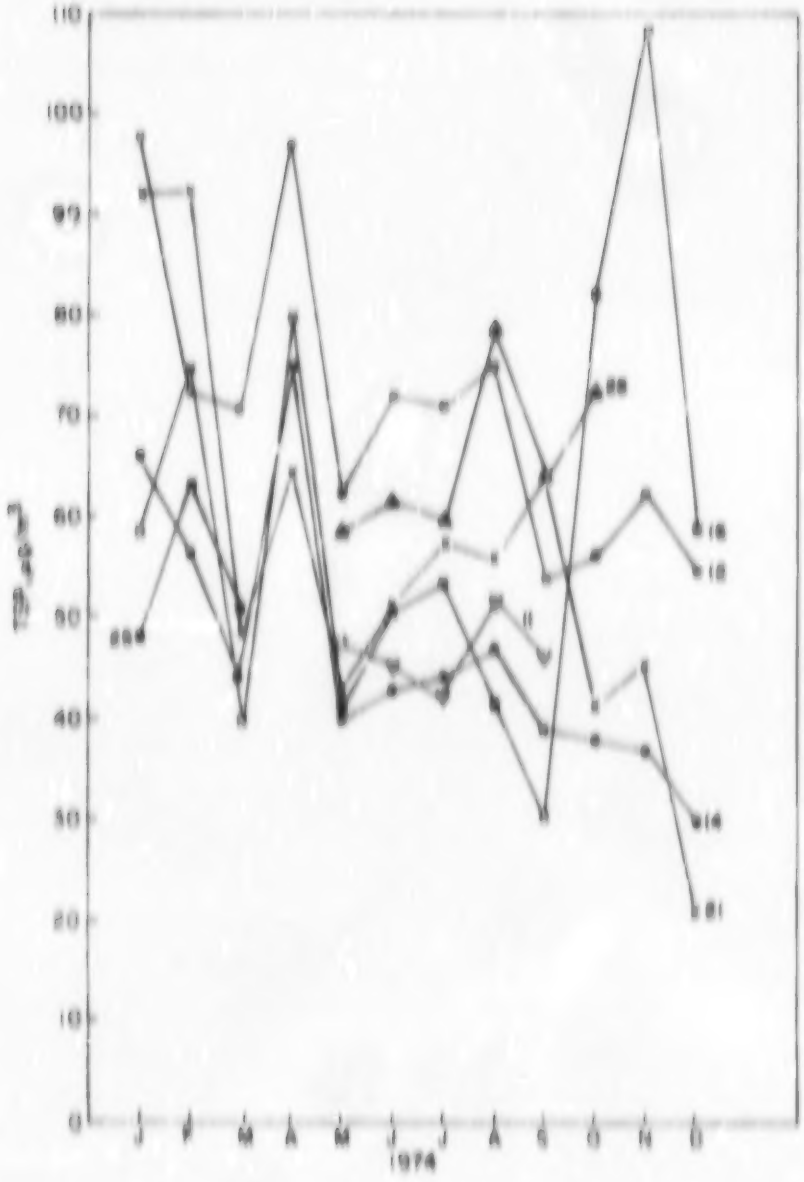


Figure 13. Seasonal TRP patterns at suburban-residential sites

present monthly average TSP data. In 1974, the number of days of precipitation (Figure 8) followed the normal pattern, except for a sharp decrease in February when there were only 2 days of rain. Overall, there were fewer than average days with precipitation in 1974. Average yearly rainfall is 59.8 inches while in 1974 there were only 49 inches; hence the amount of precipitation (Figure 9) was less than the norm during most months of the year. In February there was a total of 0.1 inch of rain — by far the lowest in the year — and correspondingly, the citywide average of TSP levels peaked for the year. Rainfall was also substantially lower during April and October, months which had high TSP levels. In opposition to this, August had the highest monthly rainfall for 1974 as well as high TSP levels.

Wind speed and direction are significant in their effects on transport and dispersion of pollutants in the area. Based on wind speed and mixing heights, Miami has favorable dispersion with no episode days predicted during the average 5-year period (on an episode day, mixing height $\leq$ 1000 m and wind speed $\leq$ 4.0 m/sec).

The general seasonal trend is toward decreasing TSP levels as the calendar year progresses (see Figures 10 through 13). A possible factor in this is that mean mixing heights are higher in the spring, summer and fall, than in the winter (Table 7). Mixing layer wind speeds are fairly constant throughout the year except for a decrease in the summer. Miami generally has very high morning mixing heights which would aid dispersion; the yearly mean is 923 m.

Surface wind speeds do not appear to affect TSP levels as much as they might, assuming that the norm is for higher wind speeds causing dispersion and lower pollution concentrations. It seems, in contrast, that the influence of wind in Miami may be to resuspend particulates within the city because the seasonally highest wind speeds (see Figure 14) do occur in conjunction with most of the peaks in citywide TSP concentrations — e.g., April, August and October in 1974.

Table 7. DISPERSION CHARACTERISTICS FOR MIAMI

	Annual		Winter		Spring		Summer		Autumn	
	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM
Mean mixing height (m)	923	1351	707	1221	980	1459	1071	1383	933	1341
Mean wind speed through the mixing layer (m/sec)	5.3	6.3	5.7	6.5	5.9	6.9	4.5	5.5	5.3	6.2
Median $\bar{X}/Q$ for a 10-km city (sec/m)	10	10	10	9	10	9	10	10	10	9

Wind direction is also an obvious factor in particulate transport. Winds in Miami are normally from northerly directions in the late fall and winter - November, December, nd January - and from the southeast or east during the rest of the year. During 1974 resultant wind directions were more from easterly directions throughout the year, and on an annual scale this probably accounts for the departure of 1974 from the anticipated precipitation effect.

On a shorter time scale, however, this would indicate a TSP contribution from the Atlantic Ocean and even possibly from Africa. A study has shown that particulates from the Sahara Desert are transported across the ocean by the subtropical jet stream and can influence air quality in the West Indies. This effect is greatest during the summer months and is believed to be impacting the Miami area also. This could account for the fact that TSP levels did not decrease despite heavy rainfall in June and August, 1974, for example. This was a particularly dry year in North Africa, so there may have been a large amount of fugitive dust from the desert. Monthly average dust concentrations at Barbados are significantly higher during June, July, August and sometimes May and/or September. Trade winds carry the dust, which originates in North Africa. Miami is northwest of Barbados, but still generally west of the Sahara area. In the summer,

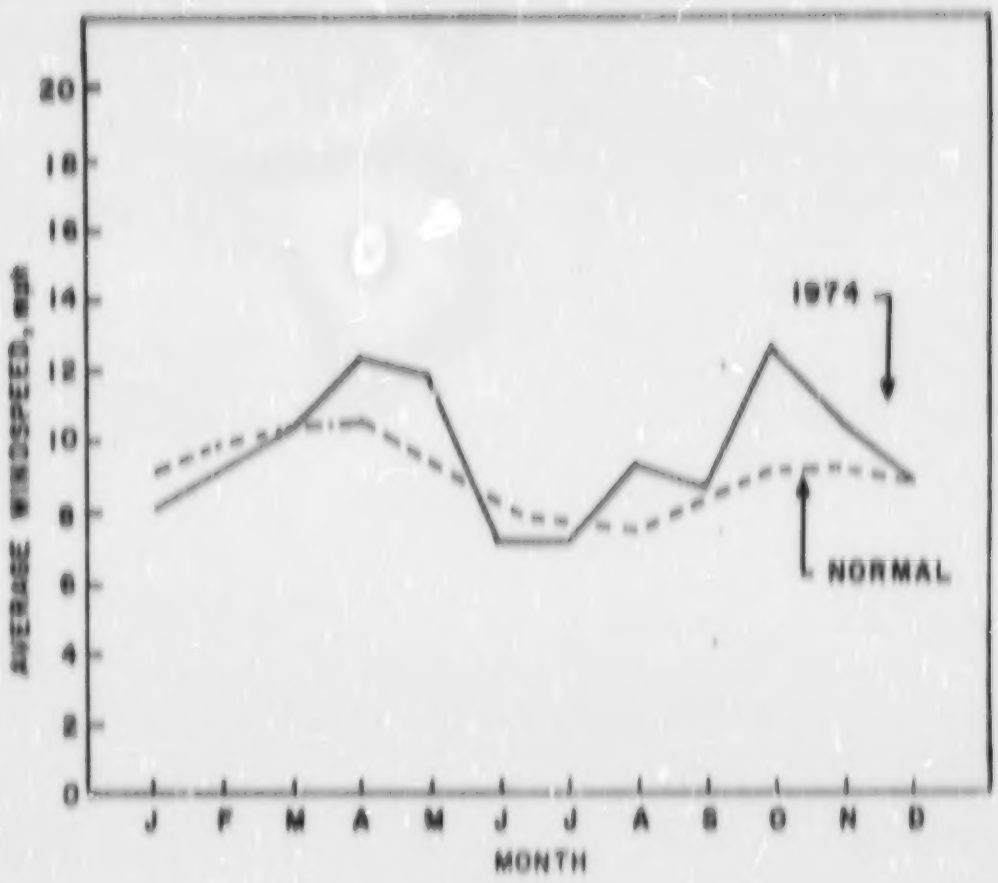


Figure 14. Average monthly windspeed in 1974 in Miami

winds are normally from the southeast; in 1974, summer resultant wind directions were east-southeast. This could be a reason for winds appearing to carry particulate pollution into, not out of the city.

Wind direction also has an obvious influence on the identification of which sources contribute the particulates monitored at each site. Wind direction frequencies on sampling days are shown in Figures 15 and 16 for sites 10 and 12. These sites are located near Miami International Airport, where the wind direction readings were taken. Site 10, a center city-residential site experienced a relatively high annual mean TSP concentration in 1974; 75 $\mu g/m^3$. Winds were most frequently from the east and less often from the northwest, on sampling days, as shown in Figure 15. The highest particulate levels do not occur with the most frequent winds - TSP concentrations at site 10 were lowest when the wind was from the northeast quadrant; i.e., when the wind came from the ocean over the resort and residential areas of Miami Beach. Figure 17 is a pollutant rose, indicating the average TSP level recorded from each wind direction (wind directions are for every 10^0). On sampling days, winds are mostly (52 percent of the time) from the east, southeast, and northeast, and during 16 percent of the time they were from the north to northwest. Land use in the immediate vicinity (within a 1000-foot radius) of site 10 is mostly residential, with some smaller areas of parking, natural, and commercial areas. There are no major point sources in the immediate vicinity.

Site 12 is characterized as a suburban-residential site, again with a reasonably high annual geometric mean TSP level of 70 $\mu g/m^3$. Winds during sampling days are mostly (53 percent) from the east-northeast and southeast, and partly (18 percent) from the north and northeast (Figure 16). Surrounding land use is primarily residential, interspersed with some commercial sections and a golf course. There are no point sources in the immediate vicinity; however, the narrow TSP peaks in the pollutant rose in Figure 18 indicate that there are sources of particulates to the south and southeast; Miami International Airport may be this nearby source.

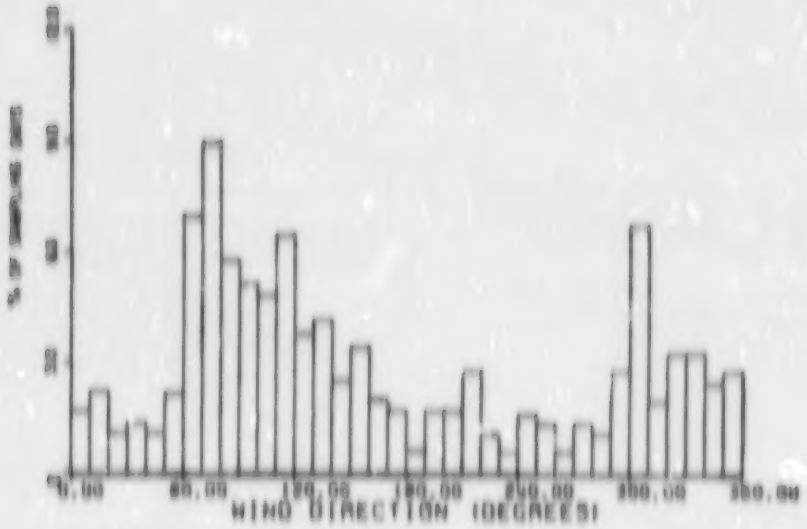


Figure 15. Wind frequency on sampling days at Site 10

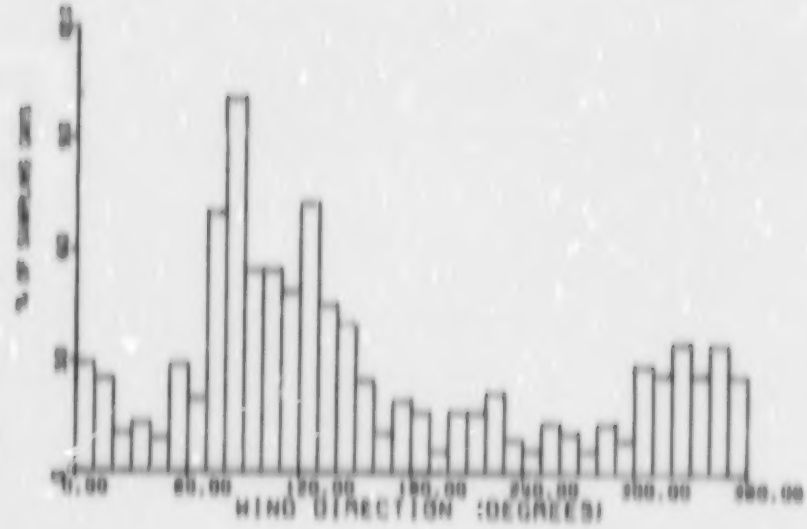


Figure 16. Wind frequency on sampling days at Site 12

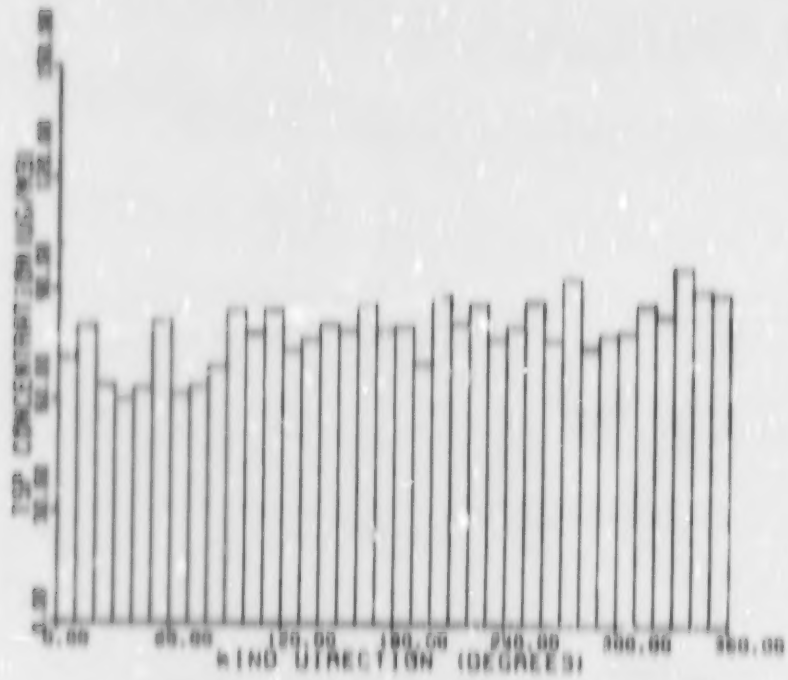


Figure 17. Pollutant rose for Site 10

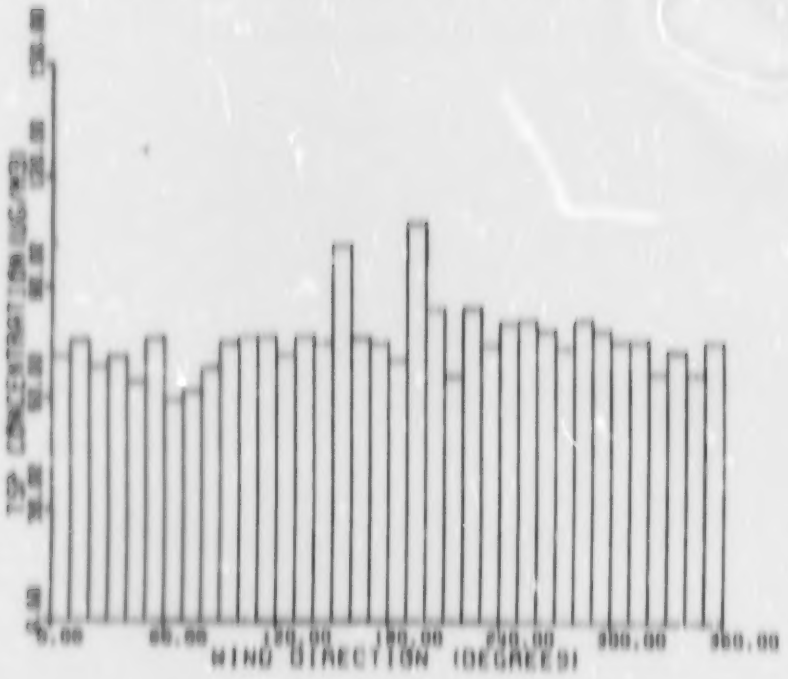


Figure 18. Pollutant rose for Site 12

Overall it appears that no one meteorological factor can be held accountable for increases and decreases in TSP levels. A combination of low rainfall and high surface wind speeds may account in part for high concentration of particulates in April and October during 1974. In February, the extremely low rainfall could be the major factor and in August high winds could be the prime cause of the high TSP concentrations measured during those months. Wind direction and nearby sources would also be influential. Extremely high particulate emissions of the hurricane season are examples of individual circumstances causing changes in TSP levels which would show up in a monthly average. However, because sampling is not done on a daily basis in Miami, it is difficult to pinpoint and correlate immediate effects on TSP there.

TRAFFIC AND OTHER URBAN ACTIVITY

In Miami, as in other nonindustrial cities, TSP levels within the urban area are higher than the general nonurban background levels. Because of the generally low level of industrial and space heating emissions in the Miami area, it presents a good opportunity to study the causes of such elevated TSP levels. It is, for example, suggested extensively in the technical literature that motor vehicle traffic is responsible for a significant portion of the ambient TSP levels in dense urban areas.

Consequently, a case study was conducted in the Miami area to investigate the relationships between residential and commercial land uses, traffic volumes and TSP levels. The specific purposes of the study were to investigate the effects of residential and commercial land use activities and traffic volumes on TSP and to consider the extent to which possible predictive models should focus on these variables.

In order to test the hypothesis that residential and commercial land use activities and traffic volumes contribute significantly to TSP, the following information was compiled for as many monitoring sites as possible:

- 1974 annual geometric mean TSP levels and 24-hour values
- 3-hour wind direction readings, resultant wind direction, and average 24-hour wind speed
- Height of the monitor
- Perpendicular distance between the monitor and the nearest major street
- 1974 average daily traffic (ADT) on the nearest major street
- Land use inventory within a 1000 foot radius of the monitoring site and classified into the following categories:
  - Residential (apartments, houses, trailers, etc.)
  - Open (undeveloped, golf courses, baseball fields, etc.)
  - Commercial (public buildings, light industry, stores, etc.)
  - Streets and parking (auto junk yard, paved/unpaved parking, streets and highways and related medians interchange areas and embankments)

The following relationships were investigated, illustrated graphically and, in some cases quantitatively with estimated multivariate regression statistical techniques:

- Percent residential and open land uses within a full 1000 foot radius versus TSP levels
- Percent residential and open land uses in the upwind sector (60 degrees) of a 1000 foot radius versus TSP levels
- ADT on the nearest major street versus TSP levels
- Perpendicular distance to the nearest major street versus TSP levels

- Combined effect of ADT and perpendicular distance to nearest major street on TSP levels
- Pollution rose and land use for each site
- 24-hour average wind speed, direction, land use and TSP values

The following observations were made:

- Annual average TSP appears to decrease with increasing percent residential and open land use (as opposed to commercial and streets and parking)
- Sites with the highest TSP levels appear to have the following common characteristics:
  - Contiguous upwind land use is primarily commercial and streets and parking
  - Site is relatively close to a major or particularly dirty street
- Annual TSP levels do not appear to be as sensitive to the land use in the upwind sector as they are to the land use within the full circle
- TSP appears to increase as the ADT on the nearest major street increases and as the perpendicular distance to that street decreases
- The lowest TSP readings occur when the wind is from the east (between 80° and 130° approximately 40 percent of the time) independent of land use in the upwind sector
- The highest TSP readings occur when the wind is from the west (between 270° and 310° approximately 10 percent of the time) independent of the land use in the upwind direction
- No conclusive relationship between wind direction, wind speed and TSP readings could be identified.

The apparent relationship between annual TSP levels and various parameters measuring the density of general urban activity and vehicular traffic was strong enough that an effort to develop an appropriate quantitative predictive relationship seemed warranted. After preliminary analysis, two

parameters in particular were studied extensively, in other cities as well as in Miami.

The primary land use parameter was based on an inventory of land use in the vicinity of the monitoring sites that was developed specifically for this case study from planning data, maps, and aerial photographs provided by Dade County planning authorities. This parameter, the percent of land in a 1000-foot radius around the site either used for residential purposes or kept open, was the best of a number of similar parameters calculated from the land use inventory, including several involving only land use in a generally up-wind sector. Figure 19 presents a plot of the TSP versus percent residential and open land use for eight Miami sites, with additional annotations about particular activities with potential impact on TSP levels. (The eight sites included were those for which both land use information and traffic data were available; the latter was the more significant constraint.) Note that, with the exception of site 24 and possibly site 10, the points all fit an inverse linear relationship very well. Site 24 is believed to be low because it is well sheltered and is the nearest of the eight to the ocean. The departure of site 10 was somewhat less understandable; it has apparent nearby sources of fugitive dust entrainment, but not to a dominant extent. Subsequent analysis suggests the departure is due to heavy trucking activity beyond the 1000-foot circle studied (see Particle Characterization).

The second parameter subjected to extensive study was a combination of traffic volume (average daily traffic, or ADT) and monitor placement, expressed as slant distance from the roadway to the hi-vol. Figure 20 presents a plot of this relationship, with site 10 again showing higher TSP than anticipated. The use of ADT per slant distance was the result of fairly extensive consideration of a number of ways of parameterizing monitor placement. The use of ADT alone, or in combination with either horizontal distance (d) or vertical height (h) alone, was completely unsuccessful in explaining the variation on TSP levels. A variety of

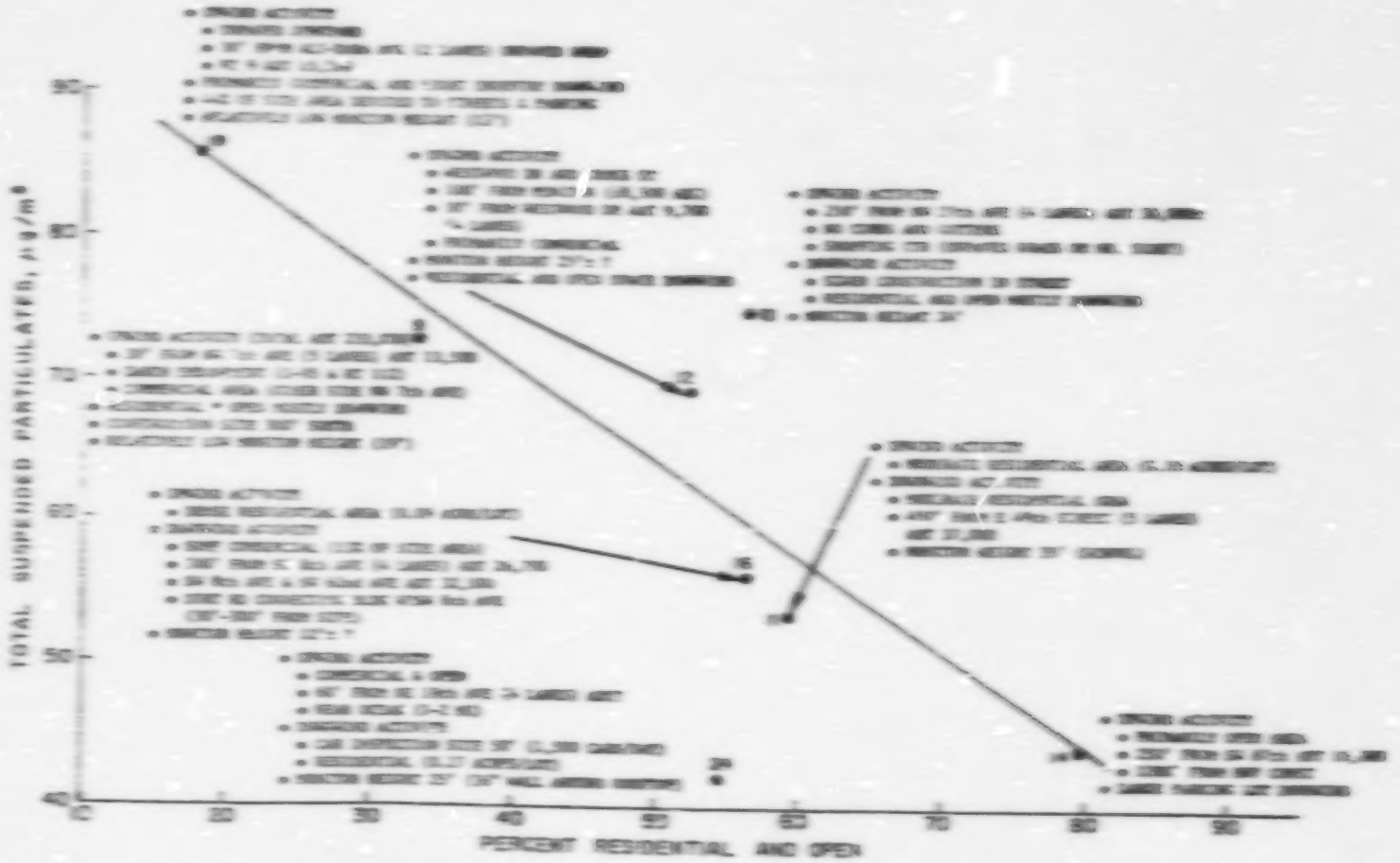


Figure 19. TSP versus percent residential and open land use (1000' radius)

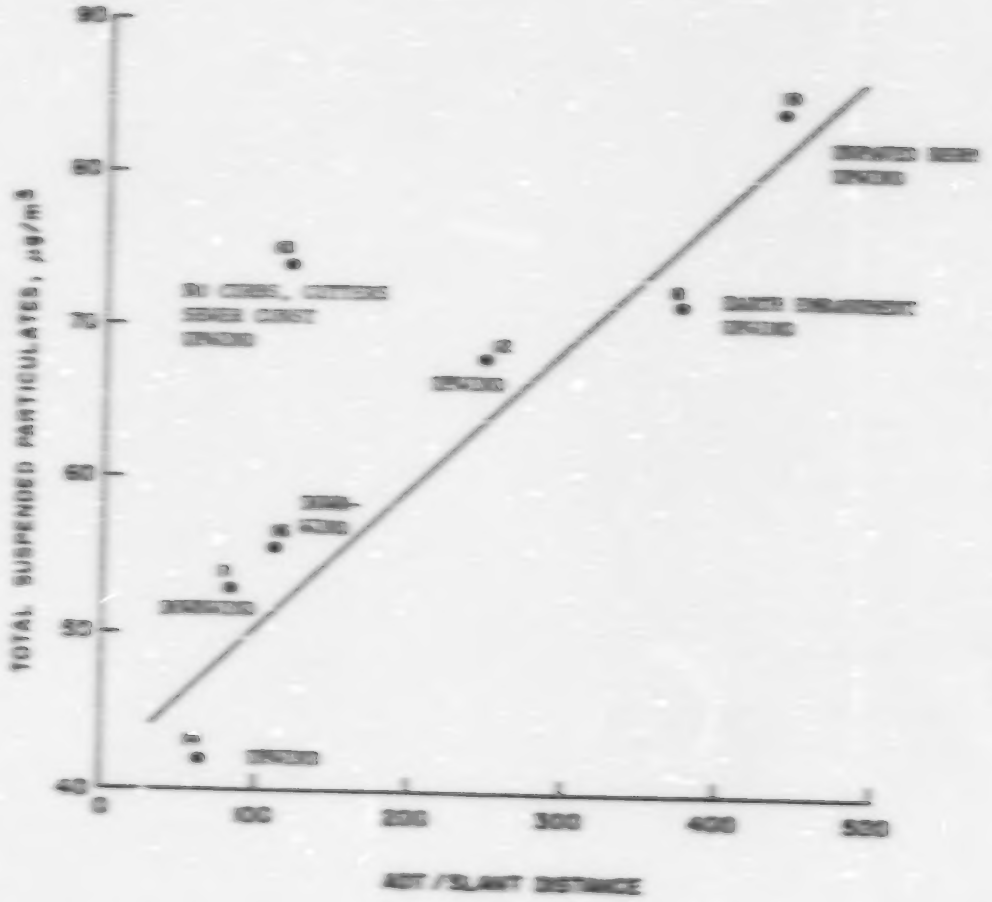


Figure 20. TSP versus ADT/slant distance

other formulations involving both d and h was also considered; based on the set of sites from Miami, there was no real basis for choosing one over another, however (see Tables 8 and 9).

Table 8. ADT PER DISTANCE PARAMETERS AT MIAMI SITES

Site	TSP, $\mu g/m^3$	ADT[a]	h, ft	d, ft	$\sqrt{h^2+d^2}$	$\frac{ADT}{\sqrt{h^2+d^2}}$	h + d	$\frac{ADT}{h+d}$	$2h+d$	$\frac{ADT}{2h+d}$	h^2+d	$\frac{ADT}{h^2+d}$
19	88	15,500	10	30	35	444	40	113	50	310	130	44
10[b]	75	30,000	25	250	251	120	275	109	300	100	825	36
8	71	11,500	10	30	36	325	40	270	50	230	130	35
12	69	9,700	20	30	39	250	55	176	80	120	430	23
16	58	32,100	10	100	101	107	110	103	120	100	444	72
11	54	27,000	35	450	451	62	485	76	520	71	1,675	39
15	44	16,100	20	250	251	66	275	59	300	56	875	18

[a]ADT on nearest major street unless otherwise noted.

[b]Site 10 in Miami is not typical in that (1) sewers construction was taking place in a nearby street and (2) surrounding streets do not have curbs and gutters. This site was not included in the regression equations.

Table 9. REGRESSION RESULTS — TSP VERSUS TRAFFIC

Description	Semi-log equation[a]	R^2	Linear equation[a]	R^2
ADT per foot giant distance ($h^2 + d^2$) versus TSP	$y = -28.1 + 41.2 \log x$	0.96	$y = 43.7 + 0.09x$	0.93
ADT per foot ($h + d$) versus TSP	$y = -41.1 + 49.0 \log x$	0.96	$y = 40.9 + 0.14x$	0.93
ADT per foot ($2h + d$) versus TSP	$y = 57.1 + 38.8 \log x$	0.93	$y = 37.7 + 0.20x$	0.91
ADT per foot ($h^2 + d$) versus TSP	$y = 40.1 + 16.0 \log x$	0.07	$y = 59.6 + 0.12x$	0.03

[a]y = TSP level

x = log ADT per foot (semi-log equation)

= ADT per foot (linear equation)

The two parameters discussed here, the percent residential and open land and the ADT per slant distance, both tend to measure the same thing, as the primary land use category beyond "residential and open" is the category, "streets and parking." Consequently, if the two parameters are used together in a regression analysis, only one can be seen to be significantly related to TSP. When this was done, the ADT per slant distance parameter was better related to TSP, though only very slightly, with either parameter explaining over 90 percent of the variation in TSP levels. This slight advantage, however, is coupled with the fact that it is much less costly to obtain the ADT data than it is to conduct the land use inventory. Consequently, for further development in other cities and the overall national assessment, the ADT parameterization was used. This does not, strictly speaking, imply that traffic alone is responsible for the TSP levels, although other information does suggest that it is responsible for a significant portion.

NETWORK DESIGN AND MONITOR SITING

The monitoring sites in Dade County are distributed fairly well in the Miami area - the populated area of the county. The monitoring network is designed to monitor manmade emissions, especially the traditional sources. Table 10 summarizes the site locations, heights, and comments about the specific site. In general, the sites are more consistently sited than in most of the other urban areas visited. In particular, the heights have a relatively narrow range and there is an apparent lack of any unusual land use or other striking anomalies.

Monitoring sites represent the various kinds of land use in the Miami area. There is little industry, so there are few sites near industrial activity - there are really no industrial sites in Miami in the sense in which they exist in other cities. The Perrine site (no. 22), characterized in the SAROAD system as "suburban-industrial" is located at the edge of the heavily urbanized area and is significantly influenced by highway traffic. The other "industrial" site (no. 20), characterized as rural-industrial, is

Table 10. DADE COUNTY MONITORING SITE CHARACTERISTICS

Dade County site no.	Location	Height above ground, feet	1984 geometric mean, TSP, $\mu g/m^3$	SASMAS site classification	Siting comments
19	3475 N.E. 163rd Ave. Opa Locka	10	89	Suburban-commercial	Local fugitive dust; light industrial
20	13301 N.W. 87th Ave.	17	74	Rural-industrial	Fugitive dust from cement crushing
11	4420 N.W. 37th Ave.	29	71	Center city-residential	Unpaved areas; sweep construction
8	1725 N.W. 7th Ave.	24	71	Center city-residential	Near freeway interchange; heavy traffic
29	18770 N.W. 57th Ave. Carol City	20	70	Suburban-residential	Nr suburban shopping center
12	201 Hammond Ave. Miami Springs	27	70	Suburban-residential	Suburban vehicle inspection station
1	95th N.W. 22nd St.	12	69	Center city-commercial	In mixed business and manufacturing area
22	14801 East Dixie, Perrine	19	67	Suburban-industrial	In small city at edge of unpaved area; influenced by highway traffic[a]
24	901 S.W. 62nd Ave., West Miami	15	59	Suburban-residential	Nr garage; occasional traffic on unpaved lot
13	Miami International Airport	11	59	Suburban-commercial	Exposed to occasional traffic[a]
21	2610 Tigertail Ave.	27	57	Suburban-residential	Near woods[a]
10	737 E. 43rd St., Hialeah	25	54	Suburban-residential	On large high school in residential area
23	9420 Bay Harbor Terrace Bay Harbor Island	12	50	Suburban-residential	Adjacent arterial road elevated
31	725 N.W. 2nd St., Homestead	17	46	Suburban-commercial	In small urbanized city[a]
14	6000 S.W. 87th Ave.	24	44	Suburban-residential	On large paved parking area; otherwise open
15	1130 Washington Ave., Miami Beach	24	42	Center city-commercial	In paved shopping area; low-volume parking adjacent
26	17200 N.W. 27th Ave., Miami Beach	21	42	Suburban-commercial	On roof of police station; used as helicopter pad

[a] Site not visited.

primarily more rural in nature, being located in a relatively undeveloped area; its high TSP levels are mainly from fugitive dust entrainment related to spillage from cement trucking.

PARTICULATE CHARACTERIZATION

Historical data concerning the composition of the suspended particulate matter in Miami is quite limited, with the NASN site having the most information. Table 11 shows the sulfate and nitrate levels at this site to be low compared to the industrialized areas of the country; the total annual average contribution of these two components is only 7 to 8 micrograms per cubic meter.

Samples from three filters at the NASN site (site 1 in Figure 2) were obtained for microscopic examination. The meteorological data for the three sampling days are summarized in Table 12, and the results of the analysis of the three filters are presented in Table 13. The results of the three analyses have also been averaged to provide a composite summary as shown in Table 14.

It is apparent that minerals predominate in the collected particulate material; Miami ranks behind only Oklahoma City and Denver with respect to the average percent minerals. The suspended particulate concentrations are lower in Miami than in many cities, however, so the actual concentration of the constituents must be scaled accordingly. Although only a limited number of samples from one site were analyzed, these results showed Miami to have the fourth highest average rubber content and to be one of only two study cities that was shown to have more rubber than combustion products. This implicates vehicular reentrainment as being at least partially responsible for the observed mineral content, which implication is further supported by the observed relationship between ADT and TSP levels.

Table 11. ANNUAL AVERAGE CONCENTRATIONS OF SULFATE AND NITRATE IONS AT THE MIAMI, FLORIDA NASN SITE NO. 10270002

Year	Sulfate		Nitrate	
	Arithmetic mean	Geometric mean	Arithmetic mean	Geometric mean
1972	5.72	5.31	1.46	1.22
1973	6.28[a]	6.13[a]	2.15[a]	1.89[a]
1974	5.05	5.13	1.87	1.45

[a]Indicates insufficient data for statistically valid year.

Table 12. METEOROLOGICAL DATA ON SELECTED SAMPLING DAYS (INTERNATIONAL AIRPORT, MIAMI)

Date	Precipitation, in.		Wind speed, mph		Wind direction, deg	
	Day of obs.	Preceding day	Average	Resultant	1-hour observation	Resultant
1/18/74	0	0	5.6	2.3	210, 10, 280, 340 220, 80, 80, 90	80
3/16/74	0	0	10.1	9.3	190, 150, 180, 180 210, 210, 230, 240	210
7/10/74	0	0.12	4.6	1.1	190, 360, 350, 330 120, 140, 0, 0	90

Note: C = Calm

Table 13. RESULTS OF FILTER ANALYSES AT NASN SITE NO. 102700G2 IN MIAMI

Date	18 January 1974			16 February 1974			10 July 1974		
tsp ($\mu g/m^3$)	90			162			108		
Components	Quantity, tenths	Size range, μm	Avg. size, μm	Quantity, tenths	Size range, μm	Avg. size, μm	Quantity, tenths	Size range, μm	Avg. size, μm
Minerals	(7+)			(8+)			(8)		
Quartz	1+	<1-30	2	1	<1-250	2	1	<1-150	2
Calcite	6	1-100	3	6+	<1-200	3	7	<1-150	3
Feldspars	1+			1+			1+		
Hematite	1+	<1-3	0.5	1+			1+		
Mica									
Combustion Products	(1)			(1+)			(1)		
Soot:									
Oil	1+			1+			1+		
Coal	1+						1+		
Glassy fly ash							1+		
Incinerator fly ash									
Burned wood									
Burned paper									
Magnetics									
Biological Material	(<1)			(<1)			(<1)		
Pollen	<1			<1					
Spores	<1			<1			<1		
Paper	<1			<1			<1		
Starch							<1		
Misc. plant tissue	<1			<1			<1		
Miscellaneous	(1+)			(1)			(1)		
Iron or steel									
Rubber	1+	<1-150	25	1	<1-300	3	1	<1-150	10

Table 14. COMPOSITE SUMMARY OF FILTER ANALYSES AT NASN SITE NO. 10270002 IN MIAMI

No. of filters	3	
	Quantity, percent	
Components	Average	Range
Minerals	(79)	75-81
Quartz	9	7-10
Calcite	62	60-65
Feldspars	4	4
Hematite	4	4
Misc		
Combustion Products	(9)	7-12
Soot:		
Oil	4	4
Coal	3	2-4
Glassy fly ash	2	1-4
Incinerator fly ash	<1	
Burned wood		
Burned paper	<1	
Magnetite		
Biological Material	(<1)	
Pollen	<1	
Spores	<1	
Paper	<1	
Starch	<1	
Misc. plant tissue	<1	
Miscellaneous	(12)	10-15
Iron or steel	<1	
Rubber	12	10-15

A further approach to considering the automotive contribution is possible utilizing data on the lead (Pb) content of TSP analyzed by the Dade County agency. The 1974 arithmetic mean lead concentrations, available for 12 of the sites in Miami (see Table 15) were compared within site classification groups. The mean at the one rural site was 0.7 $\mu g/m^3$; the commercial average was 1.4 $\mu g/m^3$; and the average of the residential sites was 0.8 $\mu g/m^3$. The high lead concentrations at commercial sites, in comparison to rural or residential sites, would again indicate the significance of the traffic contribution to ambient TSP levels. To consider the effect of traffic more quantitatively, a regression was performed on the lead and ADT/Plant Distance data shown in Table 15. The resultant correlation coefficient was 0.666, with the predictive formula:

$$TSP_{Pb} = 0.903 + 1.93 \times 10^{-3} \times ADT/SD$$

While this result is statistically significant, it is not as clearcut as the relationship with total TSP presented previously. This is apparently because the small size of lead exhaust particulates lessens the effect of fallout over distance, and because the total TSP is more significantly affected by the larger contribution from reentrained street dust.

Special Field Study

During June 1975 the Atmospheric Aerosol Research Section of EPA conducted a special ambient air sampling program in Miami. This study included both conventional and novel sampling and analysis procedures and involved sampling at Dade County sites no. 10, 11, and 14. Daily TSP levels were monitored with conventional hi-vols while special instrumentation allowed determination of elemental composition over short time intervals, the size distribution of particulates as a function of wind direction, and the corresponding elemental composition of the size fractionated samples.

Table 15. DADE COUNTY LEAD (Pb) DATA

Dade County site number	SAROAD site characteristics	1974[a] arithmetic mean TSP, $\mu g/m^3$	1974[a] arithmetic mean Pb, $\mu g/m^3$	Average daily traffic/miles distance from street
8	Centercity-residential	76.0	2.3	375
10	Centercity-residential	77.9	1.4	120
11	Suburban-residential	58.7	0.9	82
12	Suburban-residential	72.6	1.3	249
14	Suburban-residential	47.2	0.9	64
16	Suburban-residential	66.7	1.1	107
19	Suburban-commercial	90.6	1.3	444
20	Rural-industrial	89.3	0.7	
21	Suburban-residential	55.8	0.7	
23	Suburban-commercial	50.1	0.6	
25	Suburban-residential	91.4	1.0	
28	Suburban-residential	73.5	2.3	

[a]Data provided by Metropolitan Dade County Pollution Control Department.

A novel sampling device, known as the streaker,[1] allowed collection of particulate material for subsequent determination of 18 metals with a 2-hour time resolution. This device draws an air sample at a rate of 2 liters per minute through a strip of Nuclepore filter. The sampling head moves at a rate of 2 millimeters per hour which allows the collection of particulate matter for several days of unattended operation. The filter strip is then removed for elemental determination of the particulate by proton-induced x-ray emission analysis.[2] This technique is useful for determining the following elements: aluminum, silicon, phosphorus, sulfur, carbon, potassium, calcium, titanium, vanadium, chromium, manganese, iron, nickel, copper, zinc, bromine, strontium, and lead. The use of this powerful analytical technique, combined with the short time resolution of the sampling device, facilitates correlation of the chemical properties of particulate with meteorological parameters.

The AARB studies also included cascade impactors that were controlled by a wind direction sensor. Up to four impactors were operated such that each was operating only when the wind was from a desired direction. For example, each of four impactors could be run only when the wind was from a particular 90 degree sector so that the particle size distribution as a function of the four selected wind directions could be determined. The impactors utilized were low flow rate instruments so that long sampling times (e.g., 1 week) were required. The particulate collected on the impactor stages was also subjected to proton-induced x-ray emission analysis, indicating the elemental composition as a function of particle size.

The results of the study are far too comprehensive for presentation here and will be published separately by EPA. However, examination of the resulting data in the light of issues posed by the study visit provided some confirmations and emphasized the usefulness of such special monitoring data in source identification investigations.

The study included the collection of detailed data on traffic volumes at site 10; this provided an opportunity to examine the relationship between vehicular traffic and lead levels on a short time scale. In general, the analysis confirmed the common presumption that auto exhaust is the principal source of atmospheric lead and that the particle size is very small (well over half the lead was as particles of less than 0.5 μm.

The directional sampling that was conducted served to help tentatively identify the source of the elevated particulate levels at site 10. The elemental analysis by wind direction suggested a sizable source of mineral matter to the west and southwest, although the 1000-foot land use inventory prepared had indicated only residential land use in that direction. Further recourse to broader-area aerial photographs then disclosed beyond the scope of the inventory, an extensive light industrial-commercial area with apparently extensive trucking and terminal facilities, which would not have been suspected of affecting the site other than as suggested by the

directional data. Taken together with the demonstrated relationship between TSP and ADT per slant distance, this type of result, though general and qualitative, lends confirmation to the presumption that motor vehicle traffic is a significant determinant of TSP levels in Miami, probably mostly through dust reentrainment.